X-3D-BL ResearchPilot User's Manual V1.3b

Ascending Technologies GmbH

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1 Introduction

Thank you for purchasing the X-3D-BL ResearchPilot. Please read this manual carefully before you start to work with your new vehicle.

WARNING!

A motorized model aircraft is not a toy! It should only be flown by adults. Improper assembly or operating can lead to severe injuries and / or damages. Trouble with your remote control due to interferences can occur any time without prior notice. Sometimes, a model aircraft can suddenly become uncontrollable due to a failure of any component, including mechanical parts and electronics. In this case, the model can rapidly move towards any direction. Make sure you always keep a safe distance to people, animals, obstacles or things of any kind, traffic roads, etc.. There are country-specific laws regulating the operation of model aircrafts that definitely have to be obeyed. Furthermore, we strongly recommend to effect a liability insurance for model aircrafts. The manufacturer and your dealer of the X-3D-BL do not have any influence on, nor can they monitor the correct assembly and proper operation of your model aircraft. Always be aware of the dangers mentioned above and act accordingly. There is no liability of the manufacturer nor the retailer at all, as far as legally approved.

Our products are designed for the civil market only. It is strictly forbidden to use them in any military environment or to retail them to any military or military related organization. Using any of our components for larger scale flying objects is also not allowed.

SUBJECT TO CHANGE WITHOUT NOTICE.

1.1 System overview

In this section you find some information about the subsystems used in the X-3D-BL ResearchPilot. These components are also used in the hobbyist version of the X-3D-BL, however, the X-3D-BL ResearchPilot on-board software is different.

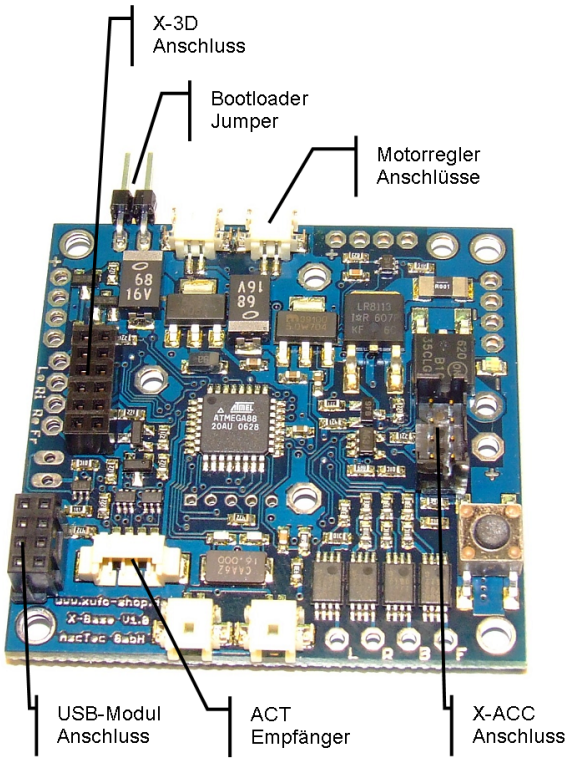
1.1.1 X-CSM

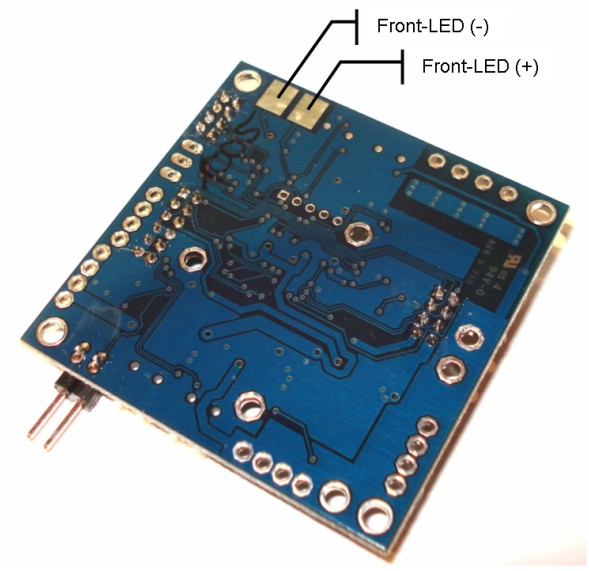
The X-CSM is the mechanical frame of the X-3D-BL UFO. The booms, which are made of a rigid carbon fiber-balsa wood sandwich material, can be replaced individually. The central unit of the frame called the "X-CSM Core" is made of light weight laser-cut magnesium parts. Being built out of these state-of-the-art materials the X-CSM is a very robust high-tech basis for your quadrotor aircraft.

1.1.2 X-Base

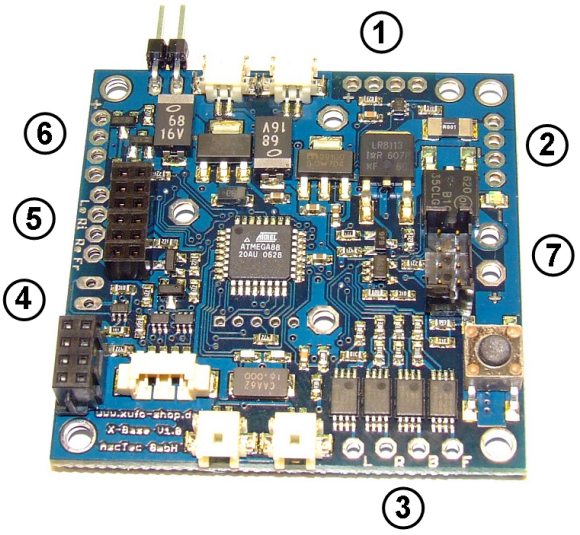
The X-Base is the central control unit which is connected to and communicates with all active elements of the X-3D-BL. Next to the battery, the motor controllers, the X-3D gyro and the receiver

you can also connect several LEDs to the X-Base to give your X-3D-BL a unique fancy look.





An LED connected to the "Front-LED" Pads on the bottom side of the X-Base will always be on as long as the X-3D-BL is turned on. Such an LED can be mounted to the very front of your vehicle to make it easier for the pilot to know where the front side is.



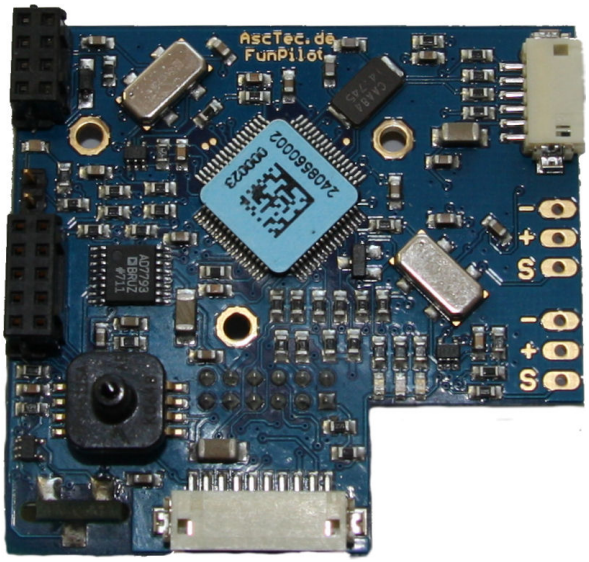
1 BL-controllers / brushed motors (+)
2 BL-controllers (-)
3 Brushed motors (-) **L**eft/**R**ight/**B**ack/**F**ront
4 PPM-Receiver Input (-) (+) Signal (from lower to upper connector)
5 LEDs (-) **Le**ft/**Ri**ght/**Re**ar/**Fr**ont
6 LEDs (+) 5V
7 Power connector, (+) and (-) marked on the upper side of the board

The key below the power connector (7) turns the X-3D-BL on and off. A short press is enough to turn the vehicle on. To turn it off the key has to be pressed for at least 200ms.

The "brushed motors" connectors of the X-Base (3) are not required as the brushless motors are driven by independent controllers, and thus the connectors can be used to drive peripherals like for instance a night-flight kit. Connector "L" is switched on and off by R/C channel 5, connector "R" by R/C channel 6. The connectors can sink currents up to 5A if they're enabled. That means that the (-)-input of a peripheral has to be connected to the "L" or "R" pad and the (+)-input has to be connected to (+) (connector (1)). Be aware that in this configuration your peripheral will be supplied the whole battery voltage. If this not what you need make sure you use a suitable voltage regulator.

1.1.3 ResearchPilot

The ResearchPilot is the sensor unit of the X-3D-BL. With three piezo-gyros, a high precision pressure sensor and highly optimized control loops it does the actual flight/attitude control. All parameters influencing the in-flight behavior can be tuned by connecting the ResearchPilot to a PC using the USB adapter that came with your X-3D-BL and the X-Control software. Once you are on the field for flying you can select four different parameter by stick commands.

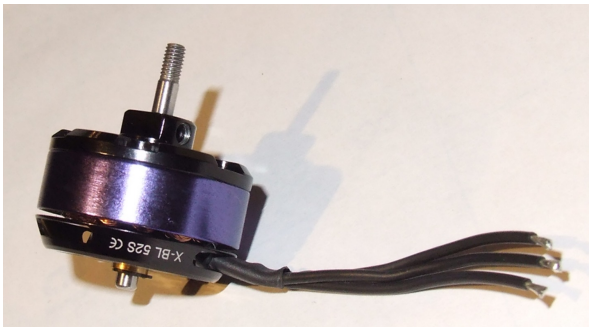


LED patterns of the X-3D-ResearchPilot

- **red:** Initialisation
- **red/yellow blinking:** X-Base or X-BL motors not detected
- **red/yellow and green blinking:** No RC reception and ne setting selected
- **yellow and green blinking:** No setting selected
- **yellow blinking/green:** Ready for flight
- **yellow blinking:** X-Base is in setup mode
- **yellow/red:** trim reset
- **gelb:** trim saved

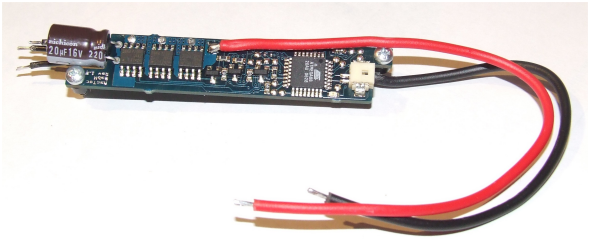
1.1.4 Motors

The X-BL-52s motors by HACKER Motors Germany are custom-built for the X-3D-BL. The motors are perfectly suited for the application in this vehicle.



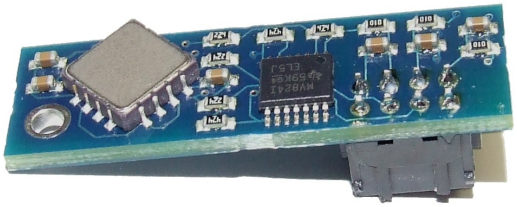
1.1.5 X-BLDC brushless motor controllers

Every motor is controlled by an independent X-BLDC brushless motor controller. The controllers are highly optimized for the X-BL-52s motors and thus ensure the highest efficiency possible. Please note that for this reason the controllers might not work with a different motor type.



1.1.6 X-ACC

The X-ACC is a tiny add-on module comprising a triaxial accelerometer.



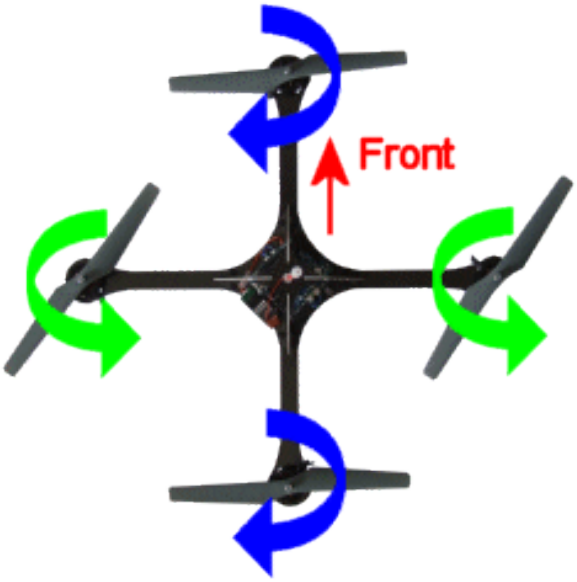
Using the acceleration data the X-3D can compute the absolute orientation of the vehicle in pitch and roll. The datafusion is done with an update rate of 1kHz to guarantee good stability. As a consequence, the helicopter is able to come back to a horizontal orientation on its own. In the X-ACC mode the pilot - or your own add-on electronics - command an absolute angle. The further you push the pitch or roll stick, the bigger the tilt-angle of the X-3D-BL. If you leave the stick centered the helicopter will come back to horizontal. In this mode you are not able to do loops or flips, however, hovering and all 2D-maneuvers are much easier to do. The X-ACC is also a great help for beginners! In addition, the vehicle can be position stabilized by a simple PD-Loop.

1.2 Transmitter

Any five or more channels R/C transmitter can be used to operate the X-3D-BL ResearchPilot. Even if it is controlled autonomously by your own controller board, the transmitter is required as a backup. As a safety measure the X-3D-BL ResearchPilot is not able to launch without a valid signal from the R/C transmitter.

2 Things to do before the first flight

The X-3D-BL is shipped completely assembled and tested. You only have to do the following steps to make it work with in combination with your equipment.



2.1 Mounting the propellers

The propellers can be slid over the axles and be fastened using a plastic nut. Do not fasten the nut too tight, as this would bend the propellers.

Please note that there are two types of propellers: One pair of propellers is spinning clockwise, the other pair is spinning counterclockwise. The propellers spinning clockwise must be mounted to the front and the rear motor, whereas the counterclockwise rotating propellers must be mounted to the left and to the right motor.

To improve the durability of the propellers during a crash you can optionally add a cable tie (e.g. 2.5 x 100 mm) as seen in the following picture.

2.2 Preparing your own battery

You need a 3s (three cells, 11.1V) Lithium Polymer (LiPo) Battery. We recommend capacities between 1500 and 2100 mAh. With a state-of-the-art 2100

mAh battery the vehicle is able to hover up to 23 minutes without any payload, and up to 12 minutes with 200 g of payload.

Make sure you mount your battery such that it can definitely not get damaged by hitting the frame, even in a crash. Otherwise the battery could explode! Here is an example of how to mount a battery correctly:

The black foam on both sides hinders it from being hurt by the magnesium parts of the frame. The woodden plate on the bottom makes it stick to the screw holding the bottom plate of the frame. Of course, there are many different ways to prepare your battery for a safe operation. This is only an example.

Lithium Polymer Batteries (LiPo) can be very dangerous if not handled correctly. Please read and follow the instructions of the battery and charger manufacturers! Do never short circuit a LiPo battery and use safe connectors!

2.3 Teach-in of your transmitter

If you want to use your own transmitter which you did not purchase bundled with the X-3D-BL ResearchPilot, please follow these steps:

First of all, you need to install the X-Control PC-Software. If you didn't receive a copy of it please contact us by e-mail. Connect the USB adapter to your PC and to the X-Base, turn on your UFO, open the X-Control software and click on "X-Base" and then on "Connect". Then choose "Receiver setup" and "Automatic calibration"and follow the instructions given by the software.

You can freely choose a stick on your R/C for every function. If you are used to a certain configuration you should definitely continue using this one. If you haven't flown other model aircrafts before we recommend the following configuration ("Mode 2"):

The X-3D-BL ResearchPilot works with any R/C with at least five channels. Make sure that all channels work independently and that no mixers are active in your remote.

Please make sure you assign a switch on your R/C transmitter to the SW1-function, as you will need this channel to activete the serial interface onboard your X-3D-BL ResearchPilot.

3 Operating the X-3D-BL ResearchPilot

3.1 Important things to keep in mind

- Directly after turning the X-3D-BL on the motors produce a short beep. It is perfectly normal that the propellers move slightly during that tone.
- Keep the X-3D-BL totally still after turning it on until the X-3D shows the yellow+green (no reception) or green (ready to fly) light pattern. Otherwise the sensors can not be calibrated correctly and the vehicle might go crazy after turning on the motors. If you accidentally moved the system during startup simply turn it off and on again.
- If only the green LED at the X-3D board is on the vehicle is ready to fly. A yellow+green light pattern means "no reception". In this case please check that your remote control is turned on and fully functional, that the receiver crystal is installed in the receiver and that the receiver is connected correctly.
- After the startup phase the motors are still turned off and secured. To turn them on you have to move the yaw stick to the very left or to the very right while your throttle stick is in zero position. The motors will then start and keep running at their minimum speed. To turn the motors off you have to do the same procedure again: Move the yaw stick to the very left or to the very right while your throttle stick is in zero position. There is no flight maneuver where one would use this control input and thus you will not accidentally turn off your motors during flight. For safety reasons you should turn off the motors immediately if one of the propellers touches the ground or any other obstacle and hence the X-3D-BL ResearchPilot is not able to take off.
- There is a battery warning implemented in your X-3D-BL. A low battery is signalized by a periodic, simultaneous tremor of all motors. This is hard to see but it can be heard. Depending on the battery you use there is about a minute of flight time left after the low-battery warning is activated. Lithium Polymer (LiPo) batteries are very vulnerable to deep discharge. That is why the X-3D-BL turns off completely if the voltage drops under a programmable threshold. You can adjust the thresholds for the low-battery warning and the low-battery shut down using the X-Control software. Therefor you have to connect the X-Base to your PC using the USB adapter and click on "X-Base", "Connect" and then on "Parameters".
- If the ambient temperature changes rapidly, for instance when you leave a warm room, the angles estimated by the datafusion algorithms might not be totally correct. As a consequence your vehicle would be tilted a bit, even with a neutral pitch and roll command. In this case we recommend to wait a few minutes, until all sensors have adopted to the ambient temperature.

3.2 Hints for using the X-ACC mode

- In the X-ACC mode it is particularly important that the vehicle is not moved at all during the initialization. Calibration errors caused by shaking during startup will influence the performance much more than in the heading-hold mode. If the vehicle tilts more and more after starting the motors, it is very likely that it was moved during the initialization. In this case, please turn it off and on again and make sure that it is not moved until the X-3D displays the green+yellow or green light pattern.

- If your X-3D-BL has the X-ACC module and the X-ACC firmwares installed it behaves different in case of a reception loss. If there is no R/C signal it will activate the X-ACC mode, try to get to a horizontal orientation and start to sink with 1/3rd of full throttle. It will keep this state until it regains reception. If one of the propellers is blocked after the landing, the X-BLDC controllers will turn off the connected motor after 10 tries to restart it. Attention! With the X-ACC installed there is no audible signal if reception is lost, as the motors are used to do a safe landing instead of playing signal tones.
- If the ambient temperature changes rapidly, for instance when you leave a warm room, the angles measured by the X-3D and X-ACC might not be totally correct. That means that your vehicle may be tilted a bit, even with the pitch and roll stick centered and the trimmers in the right position. In this case we recommend to wait a few minutes, until all sensors have adopted to the ambient temperature. You could also fly using the Heading-Hold mode during that period, as it is more robust against changes in temperature.

3.2.1 Trim memory function

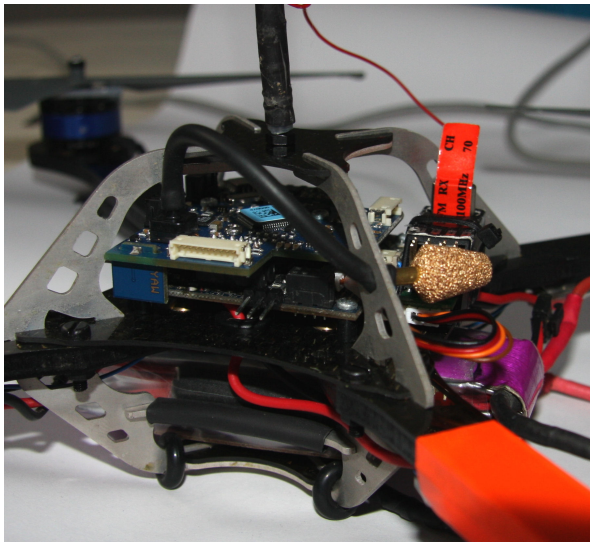
The X-3D and the X-3D-ResearchPilot are able to save the actual trim setting on your RC transmitter to enable smooth switching between X-ACC and heading hold mode. Two functions can be selected with the RC transmitter.

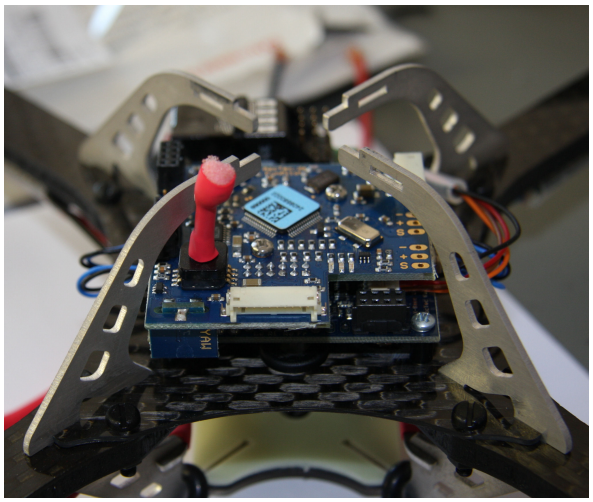
A simple method to correctly calibrate your trim memory:

- Reset trim memory (Motors off, full throttle, full yaw to the right)
- Fly in the X-ACC mode and trim the UFO
- Land, stop motors and save the trim (Motors off, full throttle, full yaw to the left)
- Set the trimmers on your remote to 0 and start flying normally.

3.2.2 Optimisation of the pressure sensor

The pressure sensor of the X-3D-ResearchPilot is sensitive to light and air movements perpendicular the the sensor opening (e.g. by wind during a forward flight). Therefore it's recommend for the best performance, especially outdoor, to add a small air filter to the pressure sensor. A prooven technique uses some schrinking tube and some foam (e.g. foam from the X-3D-ResearchPilot box). Shrinking the schrinking tube around the pressure sensor pin and carefully add some super glue to make it hold better. Attention: It's very important that absolutly NO superglue get's into the sensor! Otherwise this very expensive part can take damage! An alternative are sinter filter which you can get in your modell store. The following pictures show both variants:





3.2.3 Control modes X-3D ResearchPilot

The X-3D-ResearchPilot has three different control modes:

- Heading Hold mode(HH)
- X-ACC-mode
- X-ACC + height control Modus

Switching between the modes can be done in two different ways:

- 3-step switch teached in to channel 5 (SW1 in the X-Base configuration)
- 2-step switch teached in to channel 5 to switch between X-ACC and HH mode. A second switch teached in to channel 6 (SW2) for enabeling the height control in X-ACC mode.

The recommanded default setting is the 3-step switch. Use the second mode RC transmitters without 3-step-switched. The mode can be changed with the PC-Software seperately in every setting (in datafusion/misc).

Attention: It's very important to teach in the channels 5 and 6 in the X-Base receiver configuration! Otherwise the UFO can get uncontrolable as it's switching modes undefenately.

3.2.4 Height control

The height controller is programmed as sink and fall rate controller. Stick in the middle means: "hold height". Starting from the ground is very easy. Just push up the stick to full throttle until the UFO reached it's desired height. Then put the stick back in the middle. The UFO will try to hold it's height as good as it's possible. This mode is more meant for outdoor usage. The controller characteristics are calm and not very agressive, so it's possible and normal that the UFO doesn't climb to the desired height completlty again afer a disturbance. Light and other air flows can decrease the performance of the sensor. Using a air filter is recommanded (see 3.2.2. It's better to use a spring on the throttle stick as well if you fly often with the height control. Otherwise it can be hard to find the middle of the stick. The deadzone can be increased in the parameter settings if it's necessary. The thrust pulsing battery warnung should be switched off for the height control if you still want to fly with it at empty battery conditions.

3.3 First flight

We recommend to do the first flights on some big grassland, as the soft ground will soften possible crashes. If you have never controlled an R/C aircraft before you will have to practice a bit until you're able to fly inside your lab.

Make sure that the battery is fully charged, connected and mounted correctly. Switch on the vehicle and be *really* careful during the startup phase. The vehicle must NOT be moved during startup as the gyro sensors are being initialized! If the vehicle was moved during startup simply turn it off and on again. The startup sequence is completed once the motors start playing the preprogrammed music. Please be

aware, that the first "beep" after turning the vehicle on is part of the startup process. Once the music has been played the X-3D will light the green and yellow LEDs if the transmitter is turned off and only green if a valid signal is detected. Now the vehicle is ready to fly.

To start the motors you have to move the left stick to the very left or right whilst holding throttle in zero position.
If it is the first flight after a while or the first flight at all hold your X-3D-BL ResearchPilot down to the floor. You can grab the center part of the frame, but make sure that you don't touch any of the rotors.
In case it tries to tilt in any direction and one or more of the propellers are going crazy: Please read the troubleshooting section of this manual.

Angle stabilization in pitch and roll is active even when the propellers are running idle. Use this feature as you hold the vehicle from below and tilt it carefully to check that everything works. As you tilt it to one direction you must feel some counterforce from the motors if everything is o.k.. You can also try to steer the pitch and roll axis and see that you can directly steer the angles. Please check if the vehicle is leveled in your hand with the pitch and roll stick in neutral position. If not, correct any undesired tilt with the pitch and roll trimmers.

Now, give a little throttle and the vehicle should hover. Try hovering in a height of about 1m and concentrate on the red marking which is the front of your vehicle. Try to compensate for any movement in yaw by moving the yaw-stick in the opposite direction. It is much easier to control the vehicle if red is facing away from you, as in this case it will move away from you if you push your pitch/roll stick away. It is perfectly normal that the vehicle drifts slowly in all directions. As long as you have not installed any external tracking for position control, you have to compensate for these movements manually. After a few battery charges you will able to fly in any room, and with some more practice you can even fly in small spaces and land on tables etc.. Good luck!

3.3.1 X-3D-ResearchPilot Parameter

The X-3D-ResearchPilot offers four onboard stored parameter sets which can be selected my the RC. To select a setting make sure, that the motors are switched off and the UFO has RC reception. The setting is selected by giving full throttle and moving the pitch/roll stick to one of the four corners for a second. The UFO acknologes the selection by 1-4 beeps. The following image shows the stick positions for the different settings.

The factory set parameters are already prepared for the X-BL-Ufo. Therefore there is no direct need to change them. Nevertheless, if you want to change them connect the X-USB module to the X-3D ResearchPilot, switch on the UFO and start the PC software.

Click on "FP/OSP" and on connect to connect to the X-3D-ResearchPilot. Click now on "OSP Flight parameters".

By clicking "Load" or "Save" parameter sets can be stored on or loaded from the PC. The button "transmit" transmits the actual parameterset, but doesn't store the setting on the UFO! Only a click on "Write parameters" writes the setting in the permanent memory of the UFO.

Click on "Ready" and "Transmit and disconnect" after you done.

4 On-Board serial interface

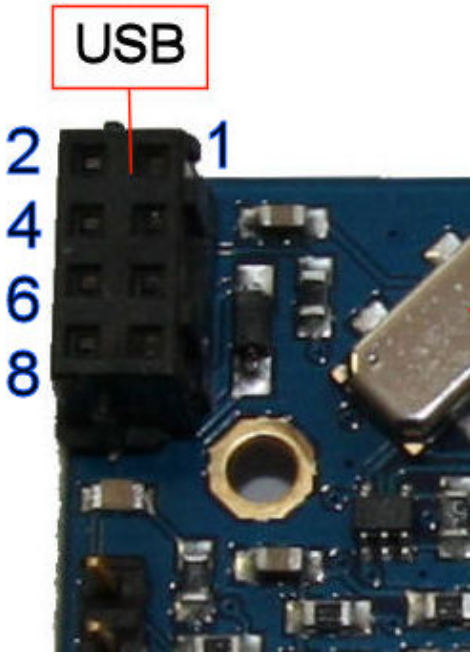
4.1 Physical interface

The interface is a serial uart link with 3.3V TTL levels which is 5V tolerant at 57600 baud, 8 bits, one startbit, one stopbit. To connect a PC, a bluetooth link or a high level processor to the ResearchPilot you can use the same interface as the USB interface:

Pin 1	GND
Pin 2	GND
Pin 3	RXD(input)
Pin 4	NC
Pin 5	TXD(output)
Pin 6	CTS(input)
Pin 7	VCC (4.3V)
Pin 8	VCC (4.3V)

Be carefull with the VCC power supply. It's connected to the analog supply of the pressure sensor and is very sensitive to noise. Depending on the needed power it might be neccessary to connect the power of your transmitter directly to the battery power (12V pins on the X-Base).

Tie CTS to GND for continuous data transfer.



Alternatively, you can use the pin as an input for a radio modem's CTS (Clear To Send) pin. The X-3D-BL ResearchPilot will only send data if the CTS pin is pulled low by the connected device. It will stop sending data if the Pin is pulled high by the modem to prevent data loss during the transmission.

4.2 Data protocol

4.2.1 Data output

The data output protocol is a very flexible user programable serial protocol. By sending a configuration packet to the ResearchPilot the data packet can be changed to a user configuration. Through the command data packet, the desired data rate can be set in 5Hz steps from 5Hz up to 300Hz which is automaticly handled by the ResearchPilot. The data packet can be configured to contain any arbitrary combination of the values from the following table. The standard packet is configured as:

ID_ANGLE_PITCH
ID_ANGLE_ROLL
ID_ANGLE_YAW
ID_AV_PITCH
ID_AV_ROLL
ID_AV_YAW
ID_ACC_X
ID_ACC_Y
ID_ACC_Z
ID_HEIGHT
ID_RC_CHAN0
ID_RC_CHAN1
ID_RC_CHAN2
ID_RC_CHAN3

The configuration packet is descriped in Section 4.2.1.

Name	*ID*	*ID#*	*Size*	*Type*	*valid Values*	*Unit*
Raw data						
gyro_pitch	ID_RAW_GYRO_PITCH	0x01	2	short	0..1023	Raw
gyro_roll	ID_RAW_GYRO_ROLL	0x02	2	short	0..1023	Raw
gyro_yaw	ID_RAW_GYRO_YAW	0x03	2	short	0..1023	Raw
acc_x	ID_RAW_ACC_X	0x04	2	short	0..1023	Raw
acc_y	ID_RAW_ACC_Y	0x05	2	short	0..1023	Raw
acc_z	ID_RAW_ACC_Z	0x06	2	short	0..1023	Raw
mag_x	ID_RAW_MAG_X	0x07	2	short	0..1023	Raw
mag_y	ID_RAW_MAG_Y	0x08	2	short	0..1023	Raw
mag_z	ID_RAW_MAG_Z	0x09	2	short	0..1023	Raw
pressure	ID_RAW_PRESSURE	0x0A	4	int	$-2^{31}..2^{31}$	Raw
temperature	ID_RAW_TEMP	0x0B	4	int	$-2^{31}..2^{31}$	Raw
Calculated data						
Angles						
angle_pitch	ID_ANGLE_PITCH	0x0C	4	int	-90000..+90000	1/1000°
angle_roll	ID_ANGLE_ROLL	0x0D	4	int	-90000..+90000	1/1000°
angle_yaw	ID_ANGLE_YAW	0x0E	4	int	0..+360000	1/1000°
angle_pitch_acc	ID_ANGLE_PITCH_ACC	0x0F	4	int	-90000..+90000	1/1000°
angle_pitch_roll	ID_ANGLE_ROLL_ACC	0x10	4	int	-90000..+90000	1/1000°
Angular velocities						
angvel_pitch	ID_AV_PITCH	0x11	4	int	-512..+512	$0,79 * °/s$
angvel_roll	ID_AV_ROLL	0x12	4	int	-512..+512	$0,79 * °/s$
angvel_yaw	ID_AV_YAW	0x13	4	int	-512..+512	$0,79 * °/s$
Accelerations						
acc_x	ID_ACC_X	0x14	2	short	-1500..1500	mg
acc_y	ID_ACC_Y	0x15	2	short	-1500..1500	mg
acc_z	ID_ACC_Z	0x16	2	short	-1500..1500	mg
acc_absolute_length	ID_ACC_LENGTH	0x17	2	short	0..1500	
translational accelerations (pseudo values)						
trans_acc_x	ID_TRANS_ACC_X	0x18	2	short	$-2^{15}..2^{15}$	pseudovalue
trans_acc_y	ID_TRANS_ACC_Y	0x19	2	short	$-2^{15}..2^{15}$	pseudovalue
trans_acc_z	ID_TRANS_ACC_Z	0x1A	2	short	$-2^{15}..2^{15}$	pseudovalue
magnetic field (calibrated)						
mag_x	ID_MAG_X	0x1B	4	int	-512..512	no unit
mag_y	ID_MAG_Y	0x1C	4	int	-512..512	no unit
mag_z	ID_MAG_Z	0x1D	4	int	-512..512	no unit
mag_heading	ID_MAG_HEADING	0x1E	4	int	0..360000	$1/1000°$
Height)						
height (filtered)	ID_HEIGHT	0x1F	4	int	$-2^{31}..2^{31}$	mm (relative)
dheight (filtered)	ID_DHEIGHT	0x20	4	int	$-2^{31}..2^{31}$	mm/s
height_reference	ID_HEIGHT_REFERENCE	0x21	4	int	$-2^{31}..2^{31}$	mm (relative)
dheight	ID_DHEIGHT_REFERENCE	0x22	4	int	$-2^{31}..2^{31}$	mm/s
speed_z	ID_SPEED_Z	0x23	4	int	$-2^{31}..2^{31}$	pseude Z speed

Name	*ID*	*ID#*	*Size*	*Type*	*valid Values*	*Unit*
Controller Data						
control outputs						
pitch	ID_CO_PITCH	0x24	4	int	$-2^{31}..2^{31}$	0..200, 100=middle
roll	ID_CO_ROLL	0x25	4	int	$-2^{31}..2^{31}$	0..200, 100=middle
yaw	ID_CO_YAW	0x26	4	int	$-2^{31}..2^{31}$	0..200, 100=middle
thrust	ID_CO_THRUST	0x27	4	int	$-2^{31}..2^{31}$	0..200
RC data						
lock	ID_RC_LOCK	0x28	2	short	0..1	1=lock
channel0	ID_RC_CHAN0	0x29	2	unsigned short	0..4096	
channel1	ID_RC_CHAN1	0x2A	2	unsigned short	0..4096	
channel2	ID_RC_CHAN2	0x2B	2	unsigned short	0..4096	
channel3	ID_RC_CHAN3	0x2C	2	unsigned short	0..4096	
channel4	ID_RC_CHAN4	0x2D	2	unsigned short	0..4096	
channel5	ID_RC_CHAN5	0x2E	2	unsigned short	0..4096	
channel6	ID_RC_CHAN6	0x2F	2	unsigned short	0..4096	
channel7	ID_RC_CHAN7	0x30	2	unsigned short	0..4096	
Misc						
uptime	ID_UPTIME	0x31	4	int	$0..2^{32}$	seconds
voltage	ID_VOLTAGE	0x32	4	int	0..255	battery voltage in 1/10V
current	ID_CURRENT	0x34	2	unsigned short	0..65535	current in 1/100A
cpu_load	ID_CPULOAD	0x33	2	unsigned short	0..1000	cycles per second

The Researchpilot also outputs a status data packet ones every command packet is send which has this structure:

```
struct SCIENTIFIC_STATUSDATA
{
        //alway = PD_SCIENTIFICSTATUS
        //#define PD_SCIENTIFICSTATUS   0x18
        unsigned char packetdescriptor;

        //flags
        //Bit 0-5 represent the actual status of the ResearchPilot!
        if the interface is disabled by the remote, all bits are 0!
        //Bit 0(0x01): Pitch control through serial interfacae enabled
        //Bit 1(0x02): Roll control through serial interface enabled
        //Bit 2(0x04): Thrust control through serial interface enabled
        //Bit 3(0x08): Yaw control through serial interface enabled
        //Bit 4(0x10): ACC-Mode on/off
        //Bit 5(0x20): Height control - on/off (only with ACC)
        //Bit 6(0x40): unused
        //Bit 7(0x80): Scientific interface enabled by Remote?
         1=Interface enabled (control through serial link)
         0=interface disabled (control through RC)
        //Bit 8..15: sendrate of the scientific packet in 5Hz
        (0=off;1=5Hz, 20=100Hz, 200=1kHz). Scientific packet
         is send for three seconds max. after the last command_data packet
        unsigned short flags;
```

```
};
```

4.2.2 Command input

All packets send to the X-3D ResearchPilot have the following frame format:

Startbyte 1: >
Startbyte 2: *
Startbyte 3: >
Length of dat in bytes (high byte)
Length of data in bytes (low byte)
DATA
CRC16 of data (high byte)
CRC16 of data (low byte)

Length and CRC16 are unsigned short types.

For calculating the CRC16 of a packet you can use the following algorithm:

```
//update crc with data
unsigned short crc_update(unsigned short crc,unsigned char data)
{
        data ^= (crc & 0xff);
        data ^= data << 4;
        return ((((unsigned short )data << 8) | ((crc>>8)&0xff))
        ^ (unsigned char )(data >> 4) ^ ((unsigned short )data << 3));
}

//calculate the CRC16 of an array of bytes with the length cnt

unsigned short crc16(void* data, unsigned short cnt)
{
        unsigned short crc=0xff;
        unsigned char * ptr=(unsigned char *) data;
        int i;

        for (i=0;i<cnt;i++)
                {
                        crc=crc_update(crc,*ptr);
                        ptr++;
                }
        return crc;
}
```

Sending the packet in pseude-c-code would look like this:

```
struct SCIENFITIC_COMMANDDATA scientificCommandData;

void sendCommandPacket()
{
```

```
  unsigned short crc;
  unsigned char b;
        unsigned char ptr;
        unsigned short length;

        ptr=&(scientificCommandData.packetdescriptor);
        length=sizeof(scientificCommandData);

        //check if serial link is open
        if (!UartInitialized())
                return;

        //calculate CRC
  crc=crc16(ptr,length);

        //send packet
  WriteStringToUart('>*>');
  WriteByteToUart(length>>8);
  WriteByteToUart(length&0xff);
        WriteArrayToUart(ptr,length);
  WriteByteToUart(crc>>8);
  WriteByteToUart(crc&0xff);

}
```

All „WriteXToUart" functions have to be replaced by user specific access to an open serial link.

With the command protocol a single or all control channels can be taken over by the serial interface. Therefore the X-3D-BL ResearchPilot must receive the following command data packet with an update rate of at least 10Hz to 20Hz up to 200Hz over the serial link:

```
 struct SCIENFITIC_COMMANDDATA
{

        //always 0x17
        unsigned char packetdescriptor;

        //pitch, roll, thrust, yaw commands. 0..4095 2048=middle
        unsigned short pitch;
        unsigned short roll;
        unsigned short thrust;
        unsigned short yaw;

        //flags
        //Bit 0(0x01): Pitch control through serial interfacae enabled
        //Bit 1(0x02): Roll control through serial interface enabled
        //Bit 2(0x04): Thrust control through serial interface enabled
        //Bit 3(0x08): Yaw control through serial interface enabled
        //Bit 4(0x10): ACC-Mode on/off
        //Bit 5(0x20): Height control - on/off (only with ACC)
```

```
        //Bit 6(0x40): overwrite ACC/Height mode control
        //(0=mode selected by RC 1=mode selected by Bit 4 and 5)
        //Bit 7(0x80): Trigger Scientific status packet (triggers a  response
        //with the actual scientific state)
        //Bit 8..15: sendrate of the scientific packet in 5Hz
        //(0=off;1=5Hz, 20=100Hz, 200=1kHz)

        //Scientific packet is send for three seconds max.
        //after the last command_data packet

        unsigned short flags;

};
```

Explanation of the command packet:

- *packetdescriptor:* Packet identifier; must always be 0x17.
- *pitch:* pitch value. 0..4095, 2048=middle
- *roll:* roll value. 0..4095, 2048=middle
- *thrust:* thrust value. 0..4095
- *yaw:* yaw value. 0..4095, 2048=middle
- *flags:* Flags:
  Bit 0(0x01): Pitch control through serial interface enabled

  Bit 1(0x02): Roll control through serial interface enabled

  Bit 2(0x04): Thrust control through serial interface enabled

  Bit 3(0x08): Yaw control through serial interface enabled

  Bit 4(0x10): ACC-Mode on/off

  Bit 5(0x20): Height control - on/off (only with ACC)

  Bit 6(0x40): overwrite ACC/Height mode control (0=mode selected by RC 1=mode selected by Bit 4 and 5)

  Bit 7(0x80): Trigger Scientific status packet (triggers a response with the actual scientific state)

  Bit 8..15: sendrate of the scientific packet in 5Hz (0=off;1=5Hz, 20=100Hz, 200=1kHz). Scientific packet is send for three seconds max. after the last command_data packet

The pitch and roll value can be converted to absolute angles in the ACC-Mode by the following formula:

$angle = value * K_stick_XXXX$ in $1/1000°$

For the yaw the following formula can be used to calculate the desired angular velocity:

$angle_vel = (value * K_stick_yaw)/2048$ in $°/s$

In heading hold mode, the K_stick_XX_expo parameters should be set to zero for a linear output equation:

$angle_vel = (value * K_stick_XXXX_HH)/65536$ in $1/1000°/s$

As a safety precaution the vehicle will switch back to the transmitter and thus manual control after 100ms not receiving data from the serial link.

The scientific config packet is used to set the desired data structure. The packet structure is:

```
struct SCIENTIFIC_CONFIG
{
        //always PD_SCIENTIFICCONFIG
        //#define PD_SCIENTIFICCONFIG   0x20
        unsigned char packetdescriptor;

        unsigned char data_select[128];
}
```

data_select holds a list of up to 128 ID-Values which define the data which is included in the scientific data structure.

The scientific data structure send out by the ResearchPilot is:

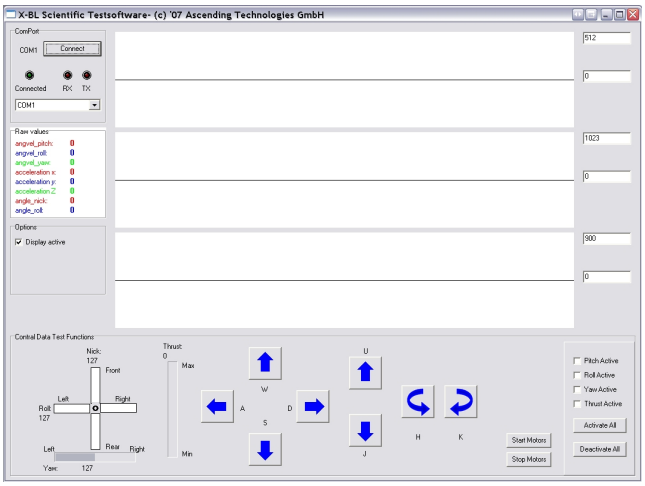
```
struct SCIENTIFIC_DATA
{
        //always PD_SCIENTIFICDATA
        //#define PD_SCIENTIFICDATA     0x19
        unsigned char packetdescriptor;
        //length of data field in bytes. Packetlength= length + 4
        unsigned char length;

        //flexible data field. Maximum 32 integers or 64 shorts.
        unsigned char data[128];
};
```

The data field contains the data in any arbitrary order descriped in chapter 4.2.1. The data bytes are distributed according the order and length of the requested data fields. A byte uses one byte of space whereas a short uses two bytes and an int uses 4 bytes.

4.3 Test software

There is a graphical user interface (X-3D-BL_ResearchPilot_Testsoftware.exe) to visualize the data packets described above. You can use this program to better understand the serial interface and to check if everything is working correctly.



If you did not receive a copy of this software please contact us by e-mail.

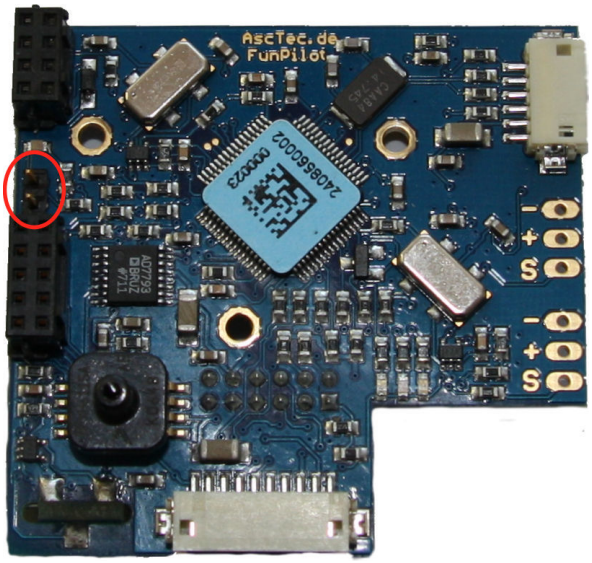
4.4 General hints for using the serial interface

To enable the command interface, the vehicle must have a stable link to a normal RC transmitter (green light on the X-3D!) and the SW1 function (see "Receiver Setup" in the X-Control software with the X-Base connected) must be >128 to activate the commands from the interface. This is a safety function as well. A skilled pilot should always be ready to take over by setting the SW1 function back to 0 (e.g. with a switch) to take control, if your high level control is not functioning as desired. The pilot also has to steer all functions that are not activated in the channel_select byte. Consequently you can activate one function after another, which makes setting up and tuning high-level control loops much easier.

5 Software updates and system configuration changes

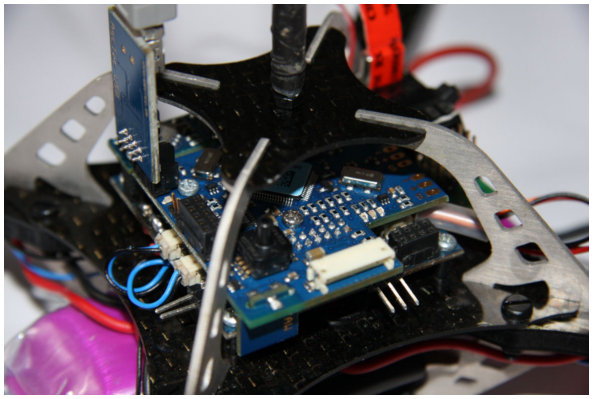
The X-3D-BL is shipped with a fully functional firmware installed on all components. Please do not upload any code from our public servers, as these versions do not offer the additional features of your X-3D-BL ResearchPilot. You only need to do a software update if you receive a new version from us.

To perform a software update you need the X-Control PC-software. If you did not receive a copy of it, please contact us via e-mail.



5.0.1 Software update of the X-3D-FunPilot

Connect your X-USB module with your PC. Afterwards click on "FP/OSP" in the X-Control software and then on "OSP Firmware Upgrade" on the left. Now connect your X-3D-FunPilot with the X-USB module.

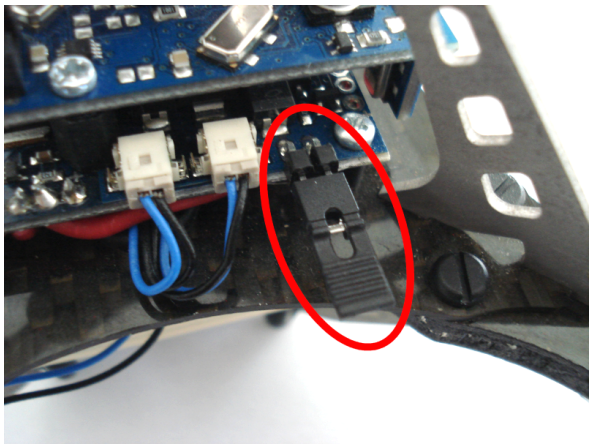


Connect the battery to the UFO. To update the X-3D-FunPilot software you need a jumper to activate the boot loader mode of the X-3D-FunPilot. Bridge the bootloader contacts and switch on the UFO.

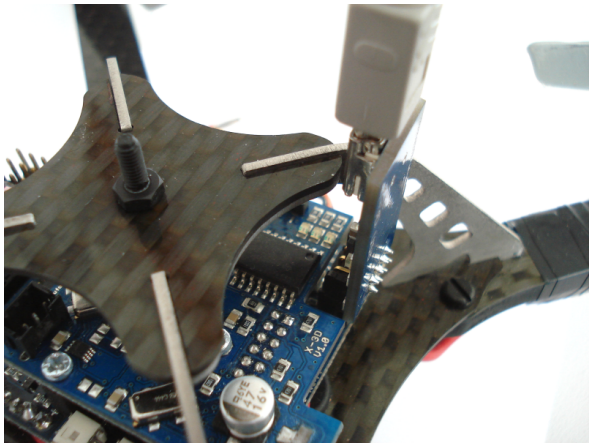
Not click on "Connect" in the PC software, then on "Choose firmware" and seleect the file "X-3D-FunPilot VX.X.hey". Click on upload and wait until the uploaded is finished. Disconnect the USB module, remove the bootloader jumper and click on "Ready". The software update is finished.

5.1 Software update of the X-Base

Again, you need a jumper to activate the so called bootloader. Set the jumper as seen in the following picture.



Open the X-Control software, click on "X-Base" and then on "X-Base firmware Upgrade" on the left hand side. Turn on the X-Base (In this case the battery has to be connected to the vehicle!) and connect the USB adapter to the X-Base.

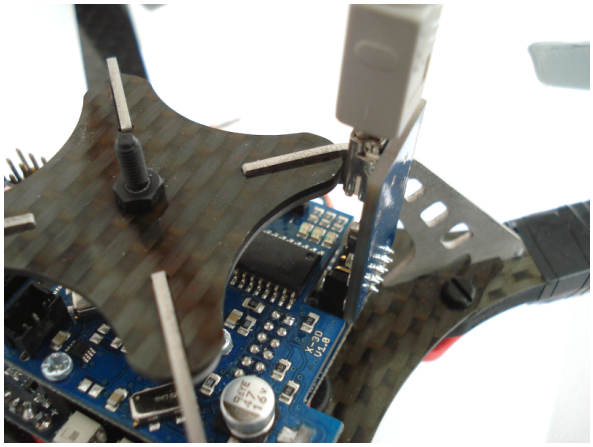


Choose the serial port (normally "Autoselect: COMxx") and click on "connect". Select the "* ACT receiver.xbs" firmware file if you are using an ACT receiver (35 or 40 MHz) or select the "* PPM receiver.xbs" if you are using a different receiver. Then click on "Upload", wait for the upload to be completed, disconnect the USB adapter from the X-Base, remove the bootloader jumper and click on "Finished". The X-Base software update is now completed.

5.2 Setting up the X-BLDC brushless motor controllers

The X-Base will not recognize all motors before they have been set up correctly. This is absolutely normal! Not until a successful configuration the X-Base will recognize all X-BLDC controllers and the X-3D-BL UFO will signal "ready to fly".

Connect the battery to the X-3D-BL, turn it on and connect the USB adapter with your computer and then with the X-Base.



Open the X-Control software and click on "X-Base". Choose the correct COM-Port (normally "Autoselect: COMxx") and click on "Connect". Chose "X-BL Setup" and click on "start search". After several seconds four brushless controllers with different serial numbers should appear in the list. If less than four controllers appear, turn of your X-3D-BL, check all solderings and connectors and repeat the previous steps.

If all four controllers have been found, click on "config" and follow the instructions given by the software in order to tell each controller its own position and the appropriate turning direction. After that, click on "Disconnect" to complete the controller setup.

Optionally a startup melody can be installed using the X-BL update function. A detailed description of how

to do this can be found in appendix B.

5.3 X-3D Parameters

If you connect the X-3D to the X-Control software without the bootloader jumper set, you can change all parameters influencing the system behaviour. You can also save a set of parameters to port it to a second vehicle, or you can upload a set of parameters which you received from us.

5.4 Calibration of the acceleration sensors

The X-3D-BL ResearchPilot comes fully calibrated. However, if something goes really wrong and for some reason you need to recalibrate the accelerometers, here is what you have to do.
Connect the X-Base with the X-Control software, open the X-ACC setup and follow the instructions given by the wizard. To achieve the best performance it is very important that the calibration is done very precise. Please check that after the calibration the X- and Y-outputs are roughly zero and the Z-output is roughly -1000 if the X-3D-BL is standing in a horizontal orientation. The automatic calibration gives usable results, but sometimes the values can still be optimized manually. Please also check the scale factors, i.e. see, if all sensor outputs are about ± 1000 if you hold the vehicle with the respective axis in a vertical orientation. If everything seems o.k. you can finalize the calibration by clicking on "Finished" and on "Transmit and disconnect".

6 Contact Information

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A Troubleshooting

This chapter holds solutions to problems which might occur during the operation of your X-3D-BL UFO.

A.1 Slight tilt in pitch/roll with the pitch/roll stick in neutral position

Due to unavoidable measurement errors it is perfectly normal, that your X-3D-BL is not always flying exactly leveled in the X-ACC mode. However, a slight tilt can easily be compensated by the trimmers on your remote control.

A.2 Considerable tilt in pitch or roll

There are some situations where the measured angle can considerably differ from the real angle, which results in big tilt-angles in pitch and/or roll while the pitch/roll stick on your remote is centered. This can have the following reasons:

- *Shaking during initialization:* In the X-ACC mode it is particularly important that the vehicle is not moved at all during the initialization. Calibration errors caused by shaking during startup will influence the performance much more than in the heading-hold mode. If the vehicle tilts more and more after starting the motors it is very likely that it was moved during the initialization. In this case, please turn it off and on again and make sure that it is not moved until the X-3D displays the green+yellow or green light pattern.
- *Teach-in of your transmitter was not correct*: To check if your transmitter was taught-in correctly, please connect the X-Base to your PC using the USB adapter and open the X-Control software to check if all channels are detected as centered if the sticks on the R/C are centered. If this is not the case repeat the teach-in of your R/C following the instructions given by the software.
- *Faulty calibration of the accelerometers:* If after restarting the X-3D-BL the unwanted tilt is still there and cannot be compensated using the trimmers on your remote, please check the calibration of your X-ACC (cf. 5.4).
- *Rapid change of the ambient temperature:* If you notice a considerable tilt in pitch or roll directly after you leave a warm room in winter or an air-conditioned room in summer, please wait a few minutes, until all sensors have adopted to the new ambient temperature. Alternatively, you can use the Heading-Hold mode during that period, as this mode behaves much more robust during fast temperature changes.
- *Extremely fast maneuvers:* Also fast maneuvers, which result in high accelerations interacting with your aircraft, can cause faulty measurements. If you fly several circles in a row in high speeds it can happen, that the measured angle differs several degrees from the real angle. If this is the case, you simply have to fly gently or hover for a few seconds until the unwanted tilt is gone.

A.3 Bad reception during flight

If the X-3D-BL does not react while it is airborne, please check if someone else uses the same channel. Make sure your TX battery is fully charged and that the antenna is fully extended. If you are still having trouble you can to the following test to check the range of your R/C system:

During the range check all other transmitters should be switched off. The best location to do the test is a big open field, as metallic objects like cars or wire fences could influence the result. You need a helper who holds your transmitter with the antenna as close to vertical as possible. Turn the X-3D-BL on and wait until only the green LED on the X-3D is on signalizing "ready to fly". Then walk away from the transmitter until the yellow LED starts flickering. At this point you should be at least 100 m away from your TX. Repeat the whole procedure with the motors running at minimum throttle. If at a distance of about 100 m the signal is still o.k. (i.e. only the green is LED on), your reception is totally fine. Due to the size of the aircraft and the associated visibility you will never fly any further away than that. If the yellow LED comes up randomly at shorter distances your TX/RX combination is to weak. In this case you can try extending the antenna of the X-3D-BL by using a longer plastic tube or stick which holds the antenna. A fully extended antenna works definitely better than one which is wound around a stick as described in this manual. If you use a stub antenna at your TX this could also be the reason for a bad reception, as such antennas do not transmit the full power. In this case try using a standard telescopic antenna instead.

A.4 The red LED on the X-3D keeps blinking after the startup

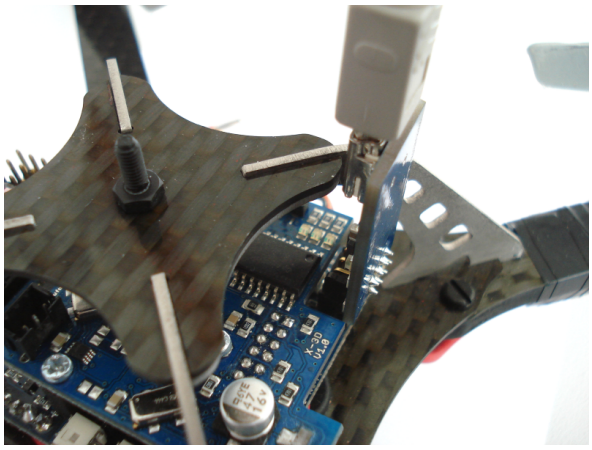
If you have not configured your X-3D-BL using the X-Control software as described above this behavior is normal. In this case please follow the instructions given in **??**. If the configuration of your vehicle was completed successfully the blinking red LED means that one of the motor controllers or motors was not detected. Please check if all four cables in black and blue color between the X-Base and the motor controllers are connected correctly. If all connections are o.k. please verify that all motors produce a short beep directly after you turn the X-3D-BL on. If one of them does not play the sound check the power connection of the affected motor controller. Are all wires o.k.? Are all soldering points clean and correct? If you connect the X-Base to the X-Control software it will show you which of the motors is not working correctly.

A.5 The X-3D-BL turns itself off during flight

Please make sure that the current limit of your X-Base is set to 35 A. To do so, please connect the X-Base to the X-Control software and click on "parameters". The value of the edit-field designated with "Current:" must be 35. Once you are done click on "Finished" and then on "Transmit and disconnect".

B User-programmable startup melodies

The X-3D-BL ResearchPilot is capable of playing preprogrammed melodies directly after the initialization. To upload a melody please connect the battery to the X-3D-BL, turn it on and connect the USB adapter with your computer and then with the X-Base.



Open the X-Control software and click on "X-Base". Choose the correct COM-Port (normally "Autoselect: COMxx") and click on "Connect". Chose "X-BL Setup" and click on "start search". After several seconds four brushless controllers with different serial numbers should appear in the list. If all four controllers have been found, click on "Firmware upgrade", then on "Select all controllers" and open the "Select firmware" dialog. Select "X-BL Startup melody (.snd)" on the lower right of the window and open any *.snd file you like, for instance from the subdirectory "X-BL Sounds" in the X-3D-BL software package. Then press "Upload".
After the upload is completed click on "Finished" and turn your X-3D-BL off and on again. After initializing it should play the new sound. Enjoy it! :-)